

AIR WAR COLLEGE

AIR UNIVERSITY

PREEMPTING THE STORM: MITIGATING AMERICA'S
NATIONAL SECURITY VULNERABILITY

TO

DISRUPTIVE MAGNETIC EVENTS

by

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Biography

Lieutenant Colonel James R. Twiford is a command Pilot and has flown numerous mobility and trainer aircraft. He has also served on the faculty of the United States Air Force Academy as an Adjunct Professor in the Department of Management, teaching accounting and investments. Prior to Air War College he served as a C-17 Squadron Commander.

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Introduction

This paper will examine the United States national infrastructure's vulnerability to disruptive magnetic events. While other sources could pose similar challenges to the components of infrastructure, this paper will focus on electromagnetic threats from hostile state or terrorist actors as well as geomagnetic disruption caused by natural phenomena, specifically geomagnetic storms. This research offers an overview of the nature of the infrastructure threat from disruptive magnetic current "events" and considers the relative probability of an event occurring. The paper explores the continuum of consequences an event would have on the nation's electrical grid, transportation and communication systems in their current state.

The paper then discusses two previous significant studies and their recommendations and attempts to put the lack of legislative policy action into context. The paper briefly discusses government roles, responsibility and readiness for an event as the United States is currently are postured. The research highlights current shortcomings in the nation's planning and readiness and calls for national level, whole of government, industry-partnered approach to planning for, preparing for and managing the consequences of an event. Finally, this paper acknowledges some examples of independent measures within the Department of Defense demonstrative of the type of planning required of all stakeholders in the system.

This research sounds a compelling alarm not for any new discoveries it makes, but for the pattern of ominous and undisputable warnings it finds have already been sounded in disparate niche areas of academia and industry but have not caused any meaningful government action. The work concludes the threat is real but could be cost-effectively mitigated by a whole-of-government effort to anticipate areas of vulnerability and measures available to harden against

the threat. The inaction thus far is most simply explained by a lack of accountability and best remedied by presidential leadership.

Sources and Probability of Significant Magnetic Disturbance

Grasping how electrically-dependent modern society has become is difficult. While in the 19th century, the nascent technology of electricity was a novelty, today it is so ubiquitous in our daily lives we contemplate its existence little more than the air that affords our next breath. As electricity grew in utility from illuminating a few light bulbs and early telegraph systems to an industrial fuel, society's reliance also increased as did the potential for damage from periods without electricity. Traditional challenges to grid reliability were mechanical breakdowns of generating equipment and distribution lines. Machinery improved as did the grid carrying the power, and redundancy became the rule. Less frequent but more intense disruptions like lightning striking a portion of the grid were significant in early industry (as they are today) but because they were easily identified and relatively frequent, science and necessity conspired to produce the solutions employed today with sophisticated grounding and design mechanisms to protect the grid as a whole and repair it as necessary from lightning strikes.

Extremely large-scale magnetic fields are less frequent and more difficult to identify than lightning. As broadly described in Faraday's Law, changes in magnetic fields are always accompanied by electric fields¹. While the earth acts as a conductor for these naturally occurring currents, the electricity resulting from a geomagnetic storm can also flow into man-made conductors like the electrical power grid, pipelines and railroad tracks. These geomagnetically induced currents (GIC) have characteristics closely resembling direct current or DC electricity.

¹ The induced electromotive force in any closed circuit is equal to the time rate of change of the magnetic flux through the circuit. Sadiku, M. N. O. (2007). *Elements of Electromagnetics* (fourth ed.). New York (USA)/Oxford (UK): Oxford University Press. p. 386

The electrical power grid is designed to deliver alternating current or AC power. So when introduced at a high intensity, GIC drives transformer cores into saturation which can disable or even destroy many components of an electrical grid, even to the point of causing chain reactions of failures across the increasingly interconnected power grids².

Nuclear Generated Electromagnetic Pulse

While research about the science behind disruptions to the power grid from geomagnetic storms has generally been piecemeal, electromagnetic pulse (EMP) has been systematically studied with military precision³ since the advent of nuclear weapons. Every nuclear weapon generates EMP directly proportional to the yield of the explosion. The effects of EMP are influenced by several other variables as well.

After the fall of the Soviet Union and particularly since the terrorist attacks of 2001, “loose nuke” scenarios have become a legitimate concern for planners and policy makers⁴. There is a wide range of expert opinion on how realistic it is to believe a non-state entity could acquire the material necessary for, correctly construct, transport and employ a nuclear device. Daniel Gardner cites the efforts of the Japanese cult of Aum Shinrikyo⁵. At the height of the radical group’s effort, it had more than a hundred scientists working on weapons of mass destruction with as much as \$1 billion in cash, a uranium mining expedition in Australia, and aspirations of developing weapons-grade material using lasers. In spite of the credentials and

² (North American Electric Reliability Corporation 2010) www.nerc.com. Pg 36 of report, “March 13, 1989 Geomagnetic Disturbance”

³ (Seiler 1975). This author was an Air Force captain developing shorthand mathematical models to allow quicker computation of EMP effects from high altitude detonations.

⁴ (W. R. Graham 2008, vi)

⁵ (Gardner 2008). Gardner’s work is on the psychology of decision making. He describes the often irrational misallocation of resources against scenarios unlikely to occur due to the effect of fear on the economic decision model.

resources in its service, the cult was unable to successfully develop or procure any operational weapon of mass destruction.

Congress formed a commission to study the security threat to the United States from an attack using electromagnetic pulse. The EMP Commission took a notably somber posture, noting delivery of an EMP device could come from off-shore⁶ using mobile ballistic missiles like Iran and North Korea have both tested in high-altitude explosion demonstrations. The commission also noted Iranian military doctrine explicitly mentions the United States' vulnerability to EMP attack. Furthermore, United Nations investigators discovered Swiss criminals affiliated with A.Q. Kahn's nuclear smuggling network possessed the design for an advanced miniature nuclear weapon able to fit within a missile procured from a rogue state.⁷

The effort, resources, and competence required to execute an EMP attack clearly make the probability low. However, it is reasonable to conclude that in the post-Cold War security environment with ubiquitous access to information, the risk is growing.

Geomagnetic Storm Frequency and Variability

For many, the idea of weather from space may sound abstract, theoretical, or even superstitious. However, its existence should not be a matter of contention at all. While admittedly a small discipline as measured by personnel and resources committed, the science of space weather has long since come of age⁸. Furthermore, it has had operational applications for years and has a recognized and growing economic role. The National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the

⁶ (W. R. Graham 2004, 3)

⁷ (Banges 2010)

⁸ (Godshall 2008, 48)

Department of Defense (DoD) have capabilities and ongoing responsibilities to forecast or observe space weather.⁹

For centuries, scientists have known solar activity is cyclical and follows patterns of increasing and decreasing magnetic activity repeating approximately every 11 years. Long before sophisticated equipment existed to measure and observe the trends, astronomers and the observant recorded the frequency and brilliance of sunspots and other activity associated with solar cycles. What is news for many, however, is the variable and powerful magnetic impact that solar weather can have on the Earth. NOAA's Space Weather Prediction Center is the nation's official source of space weather alerts, watches and warnings. The center established Space Weather Scales to more clearly communicate the likelihood adverse space weather effects would be experienced on earth. NOAA describes these space storms using a numerical scale ranging from 5 for "minor" storms to 9 for "extreme" storms.¹⁰ Minor geomagnetic storms can cause power grid fluctuations; these type storms occur approximately 900 days out of each 11 year cycle.¹¹ Extreme storms can damage grid transformers and cause grid systems to completely collapse; this level of magnetic event happens approximately 4 days per 11 year cycle.¹² The real question for planners to consider is not whether there will be another geomagnetic superstorm, but to what degree the national infrastructure is degraded and how well organized and prepared our national apparatus is to deal with the aftereffects.

National Security Consequences from Magnetic Disturbance

Making the intellectual transition from thinking of geomagnetic storms as a space oddity to a relevant subject to everyday American life is an interdisciplinary effort. Social science and

⁹ (NOAA Economics 2010, 1)

¹⁰ (NOAA Space Weather Prediction Center 2010)

¹¹ (Godshall 2008, 48)

¹² (NOAA Space Weather Prediction Center 2010)

hard science can blend into an informed narrative of science fiction when predicting the consequences to American society if its national infrastructure were debilitated. Science and drama combine in the William Forstchen novel *One Second After*, informed by U.S. Navy nuclear engineer Bill Sanders. The fictional scenario puts what can seem to be abstract scientific measurements and predictions through a narrative that begins with EMP has crippling the electrical, communication, and transportation grid¹³. What starts as a nuisance event hardly even noticed to persons at home during sunlight hours quickly becomes disruptive as fresh food begins to run out or spoil, and medicine inventories rapidly dwindle. As the weeks stretch into months and there is no revival of the infrastructure, the once modern society struggles to retain its identity as survival challenges make the environment increasingly apocalyptic.

Cold War Era Electromagnetic Pulse Testing

Long before the topic was understood enough for fiction, military researchers worked in earnest to understand the science behind and potential applications of electromagnetic pulse. In 1962 the United States and the Soviet Union separately conducted tests of EMP by detonating weapons at altitude in a series of studies to both document the debilitating effects while also evaluating the military utility of EMP¹⁴. The United States program STARFISH tested the EMP resulting from the nuclear detonation of a device around 250 miles above Johnston Island. Nearly 900 miles away, street lights in Hawaii went dark, breaker panels tripped, and a commercial telecommunications relay was rendered inoperable. The Soviet Union conducted

¹³ (Forstchen 2009)

¹⁴ (W. R. Graham 2008, 159)

similar tests. As recently as the 1990s, Russian scientists recorded tests that disabled electrical equipment and even damaged buried cables for several hundred miles¹⁵.

Historic Geomagnetic Storm Effects

While the effects of EMP remain limited to laboratory simulations and some tightly controlled government tests, there is no shortage of well-documented solar storms of great enough intensity to impact our infrastructure. The most notable incident was in 1859 and is known as the Carrington Event.¹⁶ This geomagnetic superstorm lit the night sky with an aurora so bright that campers in the Rocky Mountains could read newsprint. New Englanders observed a “perfect dome of alternate red and green streamers” over the region. The Northern Lights were seen as far south as Santiago, Chile. Telegraph lines arced or failed, some even when disconnected from their battery source would continue to operate using current from the atmosphere¹⁷.

On March 13, 1989, a geomagnetic disturbance from a solar storm wreaked havoc on North America, causing total shutdown of the Hydro-Quebec electrical power grid system in Canada, damaging transformers, depressing voltages, and tripping voltage controllers across the Northern United States. Six million people were left without power for nine hours.¹⁸ While the impact of this storm was very disruptive, its geomagnetic intensity was mild as compared to the power unleashed by the Carrington event. Estimates by Odenwald et al. from 2006 find potential economic loss to the United States economy from a storm approaching the magnitude of the

¹⁵ (W. R. Graham 2008) From the transcript to Dr. Graham’s remarks before the commission on July 10, 2008 p. 3.

¹⁶ (National Academy of Sciences Committee on the Societal and Economic Impacts of Severe Space Weather Events 2008, 7)

¹⁷ (ibid)

¹⁸ (Government of Canada, Office of Critical Infrastructure Protection and Emergency Preparedness 2002)

1859 superstorm exceed \$70 billion just from lost revenue and replacement of GEO satellites.¹⁹

The total damage considering human casualties, infrastructure replacement, weakened security and economic opportunity costs drive the figure radically further.

Previous Analysis and Recommendations

Electromagnetic Pulse Commission

In 2001, Congress passed the Floyd D. Spence National Defense Authorization Act which established the Commission to Assess the Threat to the United States from EMP Attack. The Commission reviewed existing EMP data and assessed the current threat environment. By 2004, the Commission had produced an executive level report on the threat from EMP to the United States, its allies, and forces abroad²⁰. Additionally, the Commission delivered four other classified reports to Congress in 2004 on the probability of the threat. In 2008, the organization produced its next major round of recommendations to address the measures the nation must take to be prepared. The Commission reached consensus that although our infrastructure is grossly vulnerable now, it need not be. The report concludes the associated risk could be significantly mitigated at modest cost through a coordinated effort between private and public sectors for 3 to 5 years. Furthermore, the Commission warned that inaction would mean growing vulnerability, both inviting and rewarding an attack from our enemies²¹.

National Academy of Sciences Study

NASA recently sponsored a National Academy of Sciences (NAS) study to analyze potential societal and economic impacts of severe space weather events. The workshop joined top minds among multiple disciplines to include expert testimony from representatives from

¹⁹ (NOAAEconomics 2010)

²⁰ (W. R. Graham 2004)

²¹ (W. R. Graham 2008, 7)

National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, the United States Air Force as well as industry and academia. The study's purpose was to report on space weather impacts and future vulnerabilities including electrical power systems, Global Positioning System and supporting aviation systems, and national satellite infrastructure.²² The NAS study concluded U.S. power grids continue to become more and more vulnerable to geomagnetic disruption. Intricate grid logic has allowed more efficient power distribution from areas with lowest energy generation cost to higher demand areas. While cost-effective on one level, the design pushes the grid closer to maximum capacity and makes the grid increasingly susceptible to destructive geomagnetic current spikes due to the complexity of controls and circuitry. No comprehensive design codes have been adopted to force hardening against GIC in the networks. The report highlights the expected permanent damage to transformers that is both the least appreciated and most likely outcome. Furthermore, transformers are not "field reparable" and have manufacturing lead times for replacement of a year or longer, often from foreign suppliers.²³

The recommendations from the workshop are straightforward and stark. One recommendation yielding some of the greatest benefit at lowest cost would be to require "installation of supplemental transformer neutral ground resistors," inexpensively eliminating geomagnetically induced current up to 70 percent.²⁴ The NAS study estimates the costs of a future severe geomagnetic storm if preparatory measures are not taken would be \$1 trillion to \$2 trillion in the first year, with 4-10 years required to fully recover the infrastructure. The study's assessments of GPS and satellite communication vulnerabilities are equally dire. Experts

²² (National Academy of Sciences Committee on the Societal and Economic Impacts of Severe Space Weather Events 2008, ix)

²³ Ibid 77

²⁴ Ibid 79

recounted concerns from the 2001 Rumsfeld Commission report warning of a “Space Pearl Harbor” scenario where deliberate targeting of United States space assets by an adversary would leave the country critically vulnerable. More plausible, urgent, and catastrophic, the testimony concludes, is a “Space Katrina” scenario: a space weather storm that we “should have been prepared for but were not, with effects that were much more damaging than they should have been.”²⁵

In an unrelated government effort, the president issued an Executive Order tasking the Federal Emergency Management Agency (FEMA) to review the federal government’s preparedness to deliver Presidential communication to the nation in the event of a natural disaster. During the FEMA review the electric power grid itself emerged as the principal concern, declaring the infrastructure shows “not only the potential for large-scale blackouts but, more troubling...the potential for permanent damage that could lead to extraordinarily long restoration times.”²⁶ The vulnerability warnings are clear, consistent and unambiguous. What is missing is simply a whole of government action plan in response.

Barriers to Action

One would like to think the political process would produce a rational, economics-model approach to allocate resources in a fiscally constrained environment. Ideally, the process would begin by identifying a potential threat or need; determining the probability or frequency of its occurrence and the severity or consequence of the expected outcome, and then prioritizing available resources to provide the most incremental utility.

²⁵ Ibid 82

²⁶ (National Academy of Sciences Committee on the Societal and Economic Impacts of Severe Space Weather Events 2008, 77)

Yet the United States still has no comprehensive process to protect infrastructure from the effects of a major magnetic disturbance event despite 150 years of scientific awareness, recent independent research from the National Academy of Sciences explaining the phenomenon, and a Congressionally-mandated Commission now in its ninth year of studying and identifying the consequences of an EMP event. The commission unequivocally concluded that the nation must prepare for and build capacity to respond to the infrastructure threat from magnetic events. The task is “both feasible and well within the Nation’s means and resources to accomplish.”²⁷ Furthermore, the studies found the second order effects of the infrastructure upgrades would protect against other large-scale, widespread threats such as cyber attack and other naturally caused events such as hurricanes.

The Crisis Lifecycle

Not all decision makers are rational actors, and decisions from collective bodies like Congress may have rational individual decisions ultimately resulting in a decision that does not appear to be rational for the whole. Furthermore, the lack of action can be symptomatic of a lack of leadership. President George W. Bush commented in his 20 December 2004 press conference “Many times legislative bodies will not react unless the crisis is apparent and crisis is upon them, and so for a period of time, we’re going to have to explain to members of Congress that crisis is here. It’s a lot less painful to act now than if we wait.”²⁸

This failure to act is described and explained by Braden et al. as part of the crisis lifecycle. The crisis life-cycle model has preparation, emergency, and adaptive phases. During this preparation phase, “leaders should be cognizant of tremors or signals” that would require a change to the equilibrium or a change to the status quo, which are inevitably resisted by an

²⁷ (W. R. Graham 2008, 2)

²⁸ (Bush 2004)

organization.²⁹ The resistance to adapt and respond even in the face of such a compelling need as demonstrated by these studies is irrational, particularly when compared to some extreme responses to defend against much less palpable threats like hijacked airplanes.

Daniel Gardner studies this apparent irrationality in his book *The Science of Fear*. The public's experience with power outages, for instance, is that the appropriate authorities will do everything to get the power back on, usually within minutes or at worst in a few hours. This experience can cause one to discount the consequences of future events that challenge this comforting pattern of long since taken for granted³⁰. Similarly, events for which an individual has no personal experience of overcoming but sounds both ominous and beyond control invokes a strong fear reaction. Not only a key aspect making terrorism effective, but illuminating what may explain the lack of action on more easily addressed, but less sensationalized, causes.

Proposed Congressional Action

While a citizen may reasonably be dumbfounded how it is possible that in spite of such compelling evidence of a risk with unacceptable consequences, our government has not produced legislation to coordinate a response. It is not the case that there has been no discussion or attempts made to address this possibility. By unanimous vote, the United States House of Representatives passed House Resolution 5026 on June 9, 2010. The legislation directed the Secretary of Energy to establish a program to “develop technical expertise in the protection of systems for the generation, transmission and distribution of electric energy against either geomagnetic storms or malicious acts using electronic communications or electromagnetic pulse.” Quite unfortunately, the initiative expired in the Senate Energy and Natural Resources

²⁹ (Braden 2005, 8)

³⁰ (Gardner 2008)

Committee, which instead put forth a “clean energy” bill failing to address infrastructure risk due to magnetic disturbance. No further legislation on the subject has been proposed.

Recommendations

Full-spectrum Interagency and Industry Coordinated Plan

The National Response Framework is an interagency hazards blueprint establishing a single, comprehensive framework for the management of domestic incidents. The plan provides the structure and mechanisms for coordinating federal support to state and local incident managers.³¹ The National Response Framework must incorporate large scale geomagnetic events and enjoin private partnerships already identified as essential to hardening and repairing energy infrastructure.

Beyond the National Response Framework, every individual agency in government needs to internally evaluate its susceptibilities and vulnerabilities. DoD plays a key doctrinal role in homeland security.³² It supports the national strategy for homeland security through two distinct but interrelated mission areas – homeland defense and civil support. US Northern Command (USNORTHCOM) is responsible for planning, organizing, and executing homeland defense and civil support missions within the continental US, Alaska, and US territorial waters. DoD can anticipate being called upon for the mission in the event a natural or man-made disaster overwhelms local, state, or civil federal capabilities or when a military-unique capability is required. Department of Homeland Security (DHS) assigns the Federal Emergency Management Agency (FEMA) as the lead federal agency for “incidents of national significance” to perform domestic incident management, and coordinates DoD support through USNORTHCOM.³³

³¹ (Federal Emergency Management Agency 2011)

³² (United States Department of Defense n.d.)

³³

DOD Initiatives

Until a geomagnetic event strikes the nation continues to have the opportunity to plan. With or without Congressional legislation, DoD will be called upon when a catastrophic domestic event occurs. A look to the past provides a helpful starting point for the type of planning DoD needs to be taking to retain capability in a post-event environment. Cold War planning anticipated scenarios in which aids to air navigation would be shut down with little prior notice and airborne aircraft would have to recover with minimal guidance.³⁴ This Security Control of Air Traffic and Air Navigation Aids (SCATANA) plan was devised jointly with the Federal Aviation Administration four decades ago and remains useful today as action reasonable to expect necessitated by large a geomagnetic storm.

United States Strategic Command (STRATCOM) has taken the Cold War SCATANA-type thinking one small, but important, next step forward with its “Day without Space” exercise. Speaking at the U.S. Strategic Command Space Symposium, Deputy Secretary of Defense William Lynn recently addressed the group about the vulnerabilities which accompany our growing reliance on space.³⁵ He notes our space strategy requires us to “make our space systems more resilient, and our combat power less reliant on their full functioning.” To achieve this, DoD has begun to hold exercises to endure increasing durations without space support to experience what it means to “fight through” this crucial loss. On the acquisition side, DoD continues to develop ground, air, and naval-based platforms to provide greater augmentation or redundancy of space assets.

Initiatives such as these are essential, albeit incremental, in anticipating the impact on US military capability in such an environment. As disruptive as “a Day Without Space” proves to be

³⁴ (Departments of the Air Force, the Army, and the Navy 1976)

³⁵ (Lynn 2010)

to routine operations, a “Day Without Communication” would be an order of magnitude more challenging, and a “Day Without Electricity” is complete anathema to our information-based approach to warfare.

Strategic Communication

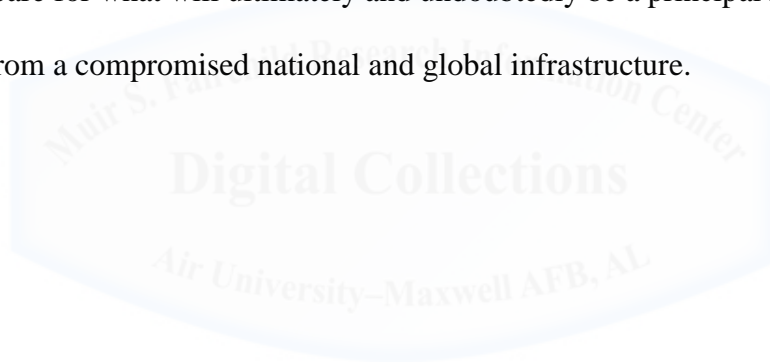
The catalyst missing from this equation is a clear owner, a responsible agent accountable for acting. While lobbying or partisan activity is inappropriate for DoD, advocating for action in broader response to security threats is not only appropriate, it is imperative and even urgent in this scenario. DoD must articulate risks, propose solutions, and offer alternative courses of action to national leadership. Understanding organizational barriers to action in the political process, the lack of a special interest group may explain the inertia faced in making the next steps past “further studies.” Wall Street effectively delivered a message to national leadership that investment banks are “too big to fail.” The country needs a comprehensive dialogue among its responsible institutions to strategically communicate its electrical, communication, and space-based infrastructure is “too essential to fail” by clearly and consistently articulating the issue from the perspective of national defense.

Conclusion

This paper underscores the near certain probability of a magnetic disturbance significantly degrading our national infrastructure unless comprehensive, coordinated, proactive measures are taken. The research demonstrates that whether caused by electromagnetic pulse or naturally occurring geomagnetic storm, the impact of these events on our infrastructure is essentially identical with potential ramifications approaching the apocalyptic. While action taken to combat the potential human actors behind an EMP threat may also be appropriate,

preparation by hardening the infrastructure and preparing to manage consequences of an EMP or geomagnetic storm event is imperative.

Significant, qualified, mainstream science initiatives independently validate the probability and expected consequences of a severe magnetic disturbance impacting our infrastructure, and demand action. The national response to this point has been woefully inadequate, and the common tendency to wait until crisis to awaken to action is not an acceptable option. Congress must pass legislation to mobilize a whole of government, interagency response in concert with private industry to harden our infrastructure, grow it more smartly and anticipate needs when it is degraded or overwhelmed by a magnetic event. In the meantime, DoD must thoughtfully prepare for what will ultimately and undoubtedly be a principal role in reacting to and recovering from a compromised national and global infrastructure.



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